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PHYTOPATHOLOGY

VOLUME XIV NUMBER 8

AUGUST, 1924

STUDIES ON A LEAF SPOT OF PHASEOLUS AUREUS NEW TO THE PHILIPPINE ISLANDS

COLIN G. WELLES

WITH PLATE XXIV AND THREE FIGURES IN THE TEXT

A serious leaf spotting of *Phaseolus aureus* Roxb. has been under observation at the College of Agriculture, Los Baños, P. I., since September 1, 1921. In the beginning the spots appeared only on the older leaves but later they spread, until on November first the plants were nearly defoliated and stems and pods were seriously affected. The development of the disease was phenomenal due to the heavy rains which commenced about October fifteenth.

Studies were made on the casual organism and the fungus was identified as *Cercospora cruenta* Sacc. While this fungus and closely related fungi are widely distributed in many parts of the Orient and America on beans, it has never before been reported from the Philippine Islands, nor has it been reported on pods of any of the species of Phaseolus, Dolichos, or Vigna on which it has been formerly noted.

Many species of cultivated beans are parasitized by Cercospora in the Philippine Islands. The relationship of these organisms is entirely unknown. The host reactions in the different cases are not at all similar. In fact there is no symptomatic ground by which the parasites may be differentiated and no work has been performed with the causal organisms which has revealed any of the fundamental physiological similarities or differences which necessarily exist.

REVIEW OF LITERATURE

Butler (1, 261-2.) in a brief statement presents the possible relationship between the various Cerosporas which he has observed on different species of beans in India. These comparisons are based entirely on morphological differences and variations in host reaction. He concludes that *C. cruenta*, which appears to be the same as the organism under consideration, is probably identical with *C. canescens*, reported from the United States and *C. vignae*, reported from Java. He also states that there is probably no difference between *C. cruenta* and *C. dolichi*. With the exception of *C. dolichi*

none of the organisms discussed by Butler have been previously reported from the Philippine Islands.

He states further that *C. cruenta* parasitizes the mung bean (*Phaseolus radiatus* Linn.[1]) in India.

Reinking (2, 248), reported a Cercospora leaf spot of *Vigna sinensis* from the Philippines but included with the note very little descriptive matter. Concerning the symptoms of the disease he says:

> "Leaves may be spotted with definite circular spots from 1 to 3 millimeters in diameter. Spots have gray centers with purplish borders."

He states further that the organism responsible for the disease is a Cercospora but includes no spore description other than that "the conidia are tapering and usually have four to six cells."

The following measurements were made from an illustration drawn to scale which accompanied Reinking's report: Conidia 21 to 70 microns long by 3.5 to 7 microns wide and conidiophores 70 to 80 microns long by 3.5 to 7 microns in width.

THE PHILIPPINE DISEASE

The plants in the field which has been under observation showed pronounced diseased conditions. The beans were planted broadcast and, as a result, the stand was very thick.

The diseased plants, in this case nearly one hundred per cent, appeared defoliated and where the leaves persisted they were sickly and severely spotted. The field had the appearance of being burned excepting in places where the leaves had escaped with a thorough scorching.

SYMPTOMS

The disease appears on leaves, pods and stems of *Phaseolus aureus* Roxb.

On the leaves:

The leaf spots are more or less circular and do not exhibit the angular form mentioned by Butler (1, 261-2). The lesions are purplish-red sometimes showing no differentiation into zones but commonly having light gray centers. The grayish centers are not confined to large lesions but are exhibited as well in lesions not more than one millimeter in diameter.

The lesions vary in size from .5 to 4 millimeters in diameter, the average falling between 3 and 4 millimeters.

In a very few instances the diseased areas coalesce and form large irregular patches limited by the leaf veins.

[1] The following note concerning the taxonomy of this plant is inserted so that confusion of host plants will be avoided to some extent. *Phaseolus aureus* Roxb. is synonymous with *Phaseolus radiatus*, the non-Linnaean species. *Phaseolus radiatus*, the Linnaean species, is commonly known as *urd* in India according to Watt (4, 880–2).

The lesions while very pronounced on the upper surface are barely discernible on the lower surface of the leaf except in advanced stages.

On the pods:

Pods which have reached a length of about 6 centimeters are seriously attacked. The younger pods appear to be free from the disease.

The pods show all degrees of attack from a few spots on each to a solid blackening and killing of the entire growth. Both young and old spots are dark purple.

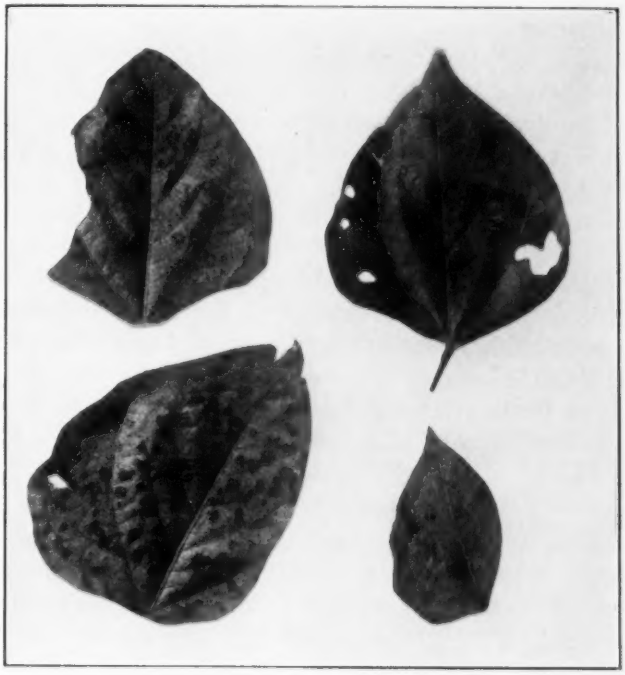

FIG. 1. Diseased leaves showing typical spots on *Phaseolus aureus* Roxb. caused by *Cercospora cruenta* Sacc.

In very severe attacks the seeds within are parasitized and become shrivelled and darkened.

On the stems:

The lesions on the stems are not so common as those on the leaves and pods, yet they may be found in considerable abundance.

The young stem lesions first appear as slightly darkened areas with the long axis of the lesion parallel to the long axis of the stem. Later the spots become darker and finally of a purplish color. Frequently they reach a length of 4 centimeters in the longest dimension.

DISTRIBUTION

The distribution of this disease in the Philippine Islands is wholly unknown. No previous mention of its appearance has been made to the writer's knowledge and at present it appears to be confined to plantings at the College of Agriculture, Los Baños.

ECONOMIC IMPORTANCE

The destruction due to this disease is remarkable. One hundred per cent of the leaves, both young and old, were attacked and exhibited from 10 to 50 lesions per leaf.

In one portion of the planting which embraced about one hectare, many leaves had fallen and frequently but two or three remained attached to each plant. In other portions the attack was less serious or at least the result was less serious, for the leaves persisted although thickly covered with diseased spots.

The pods as well as the leaves were seriously parasitized especially if they had developed to any degree of maturity. Seventy-five per cent of the pods containing partially formed seeds were attacked but young pods remained uninjured. In a few cases seeds developed to maturity but in the main they dried up either due to the diseased condition of the pod or less frequently due to invasion by the causal organism.

The spots on the stem were not so numerous as those on the leaves and pods and the direct damage by them was of little importance.

CAUSAL ORGANISM

The organism responsible for the leaf spot disease of *Phaseolus aureus* has been identified as *Cercospora cruenta* Sacc. which causes leaf spots on various species of beans. Butler (1) reports as follows concerning *Cercospora cruenta*:

> "The conidiophores emerge in clusters through the stomata. They are brown, septate, with knee-bends marking the insertion of fallen spores, as is usual in this genus, about 50 to 100 micra long by 4 to 6 micra broad. The conidia are borne terminally but the stalk continues to grow at one side so that the spores are pushed over and fall off. They are variable in size, from 50 to 140 by 4 to 5 micra, elongated, tapering above, with 2 to 8 septa, straight or slightly curved, and almost colorless."

The conidiophores of the Philippine organism measure from 55 to 91 microns in length and are 3 to 5 septate. They are typical of Cercospora conidiophores arising from stomata.

The conidia are hyaline, straight or slightly curved, obelavate, and measure from 51 to 135 microns in length by 6 to 9 microns in width, and are 3 to 7 septate.

INOCULATION EXPERIMENTS

Pure cultures of *Cercospora lussoniensis* Sacc. were obtained from *Phaseolus lunatus*. Inoculations with these cultures were made on *Phaseolus aureus*. Very interesting results were obtained which appear to bear directly on the classification of these two supposedly distinct parasites.

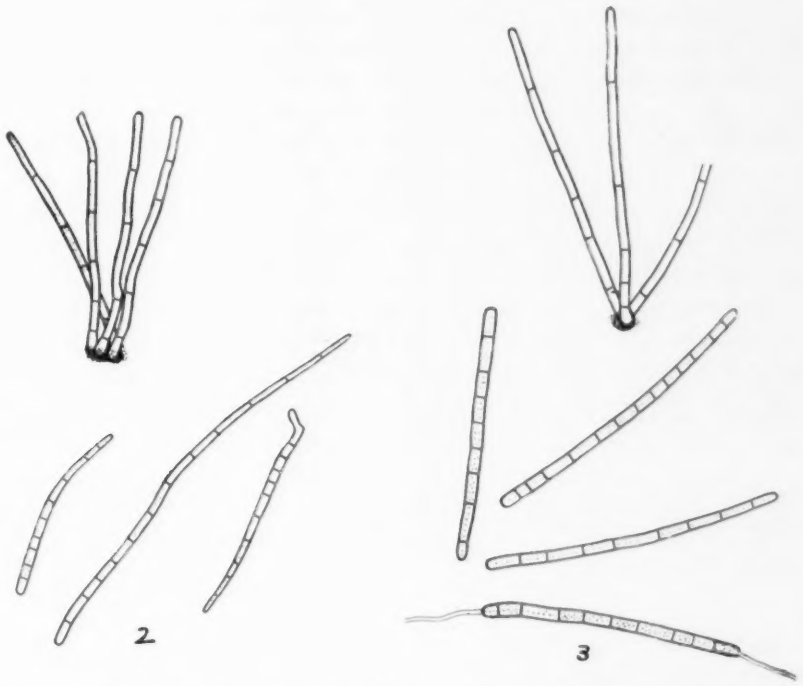

FIG. 2. Conidiophores and conidia of *Cercospora cruenta* Sacc. from *P. aureus* Roxb. Drawn by C. C. Nacoin with the aid of camera lucida (× 600).

FIG. 3. Conidiophores and conidia of *Cercospora lussoniensis* Sacc. from artificial inoculation on *Phaseolus aureus* Roxb. Drawn by C. C. Nacion with the aid of the camera lucida (× 600).

The inoculations were made in the field on young leaves in the following manner: Leaves were washed with mercuric chloride, 1-1000, and rinsed with sterile water. A mass of spores and mycelium was then removed from a pure culture and placed on the upper surface of the leaf. A wax-paper bag containing a small amount of water-saturated cotton was then tied over the leaf.

Observations at the end of one day revealed no lesion. At the end of the second day, however, a distinct, small lesion was found. After four days the leaves were removed and it was found that they bore mature

conidia on the under surface of the leaf. That the spores were borne on the under surface when the inoculation was made on the upper side of the leaf precludes all possibility of observing spores formed by the original inoculum.

The conidiophores measured 78 to 99 microns in length and exhibited 4 or 5 septations.

The conidia were nearly hyaline and measured 100 to 110 microns in length and exhibited from 8 to 11 septations.

The lesions did not appear similar to those which are naturally found on *P. aureus*. They were ashen gray in the center, yellow bordered.

Whether these two fungi are identical or not is a matter of speculation but it has been shown previously that there is a common variation in host reaction, at least with different species of host plants. The appearance of a lesion in a large measure, is due to the reaction of the host to the irritant rather than to any particular property of the causal factor itself.

The following table gives the comparative conidiophore and conidial measurements of *C. lussoniensis* on *P. lunatus*, of *C. lussoniensis* and *C. cruenta* on *P. aureus*.

TABLE 1.—*Comparative conidiophore and conidial measurements on Phaseolus lunatus and Phaseolus aureus.*

	Conidiophores		Conidia	
	Length	Septation	Length	Septation
C. lussoniensis on *P. lunatus*	90–221 *28–35	3–6	59–101 *35–45	2–9 *3
****Cercospora sp.* on *Vigna sinensis*	70–80	8–9	21–70	3–5
C. lussoniensis on *P. lunatus* (Inoculation)	78–98	4–5	100–110	8–11
C. cruenta on *P. aureus*	59–91 ***50–100	3–5	53–153 ***50–140	3–7 ***2–8

*After Saccardo, ** Reinking, and *** Butler.

The conidiophore and conidial measurements as reported by Saccardo in his original description and those obtained from Los Baños material show a striking discrepancy. The season of the year when the Saccardo material was collected is not recorded but it is likely that it was obtained during a period of rather slight precipitation. The measurements which were made by the writer were obtained from material collected during the rainy

season. When collected during the drier seasons of the year the lengths are considerably less.

The conidial measurements obtained from inoculation of *P. aureus* with *C. lussoniensis* are not sufficiently different from those obtained on the same host from natural field infection to make it possible to state that the organisms are morphologically distinct. The writer has found that moisture effects the length of conidiophores and conidia to a great extent and so it is very understandable that the larger size of the spores obtained from artificial inoculation may be due to the higher moisture which is present under conditions of artificial inoculation.

CONTROL

Several experiments have been performed in an attempt to control Cercospora diseases of *Coffea sp.*, *Averrhoa carambola*, and *Solanum melongena*. In each instance successful results were obtained and in experiments where Bordeaux mixture was applied every two weeks for no less than five applications, there was nearly absolute control. As the leaf spot of *Phaseolus aureus* is caused by a Cerospora and as the disease parallels those experimented with it is reasonable to conclude that Bordeaux mixture when applied at the intervals suggested above, will successfully control the disease.

This recourse, however, is not recommended for Bordeaux mixture required in spraying a crop such as the one under discussion is very expensive and the cost involved would be in excess of the value gained by the increase in yield.

Butler (1) suggests the development of resistant varieties. This solution must be accomplished if present cultural practices are not abandoned.

The disease on *Phaseolus aureus* has been noticed only during periods of heavy rains. If this is always true, a possible solution of control, lies in making plantings at that time of the year when rainfall is slight. These beans grow well in any season.

SUMMARY

1. A leaf spot of *Phaseolus aureus* has appeared in the plantings at the College of Agriculture, Las Baños, P. I.

2. The disease appears to be caused by *Cercospora cruenta* Sacc., which is responsible for leaf spot diseases of various species of beans in the United States, India, Ceylon, and China.

3. The disease is very serious and inhibits pod development due to defoliation or partial destruction of the photosynthetic area of leaves. About 100 per cent of the leaves and 75 per cent of the older pods are attacked. Stems are less frequently parasitized.

4. Inoculation experiments with pure cultures of *Cercospora lussoniensis* on *Phaseolus aureus* produces symptoms slightly different from those caused by *Cercospora cruenta*. Conidiophores and conidia were of approximately the same length and appeared very similar. A close relationship between these two species of Cercospora is suggested.

5. While it is believed that Bordeaux mixture will successfully control the disease, it is not recommended because of the cost involved. Resistant varieties and a change in cultural practice are suggested as possible means of combatting the disease.

UNIVERSITY OF WISCONSIN.

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FIG. A. (Upper.) Photograph of a field of beans (*Phascolus aureus*) taken about the first of September, 1921. This photograph was taken to demonstrate the vigor and prolificness with which this crop grows in the Philippines.

B. (Lower.) A photograph of a small section of the same field made about the first of November of the same year. The plants are nearly defoliated. The pods were seriously diseased and the entire crop was an utter loss.

SIMULTANEOUS SURVEYS FOR STEM RUST: A METHOD OF LOCATING SOURCES OF INOCULUM

E. M. Freeman and L. W. Melander

With One Figure in the Text

INTRODUCTION

It is obvious to anyone familiar with the details of operation in the barberry eradication campaign that one of the most difficult problems is to locate the last few bushes, those few stragglers or seedlings that have escaped all efforts to find them. It is highly important not only that these bushes finally be located and destroyed but that they be located and destroyed at the earliest possible moment. There is always the potential factor of an early start of the rust from such bushes and furthermore there is the certainty that these bushes, if not eradicated, will spread barberries to the adjacent territory through seed formation. As long as such bushes remain, the final effect of eradication can neither be determined nor realized.

It also is obvious that a mere repetition of the original methods, *viz.*, survey and resurvey, would be expensive and could not hope to give complete eradication in the immediate future. Numerous cases have been recorded in the present campaign in various states where barberries have been located through the local epidemics which they have produced. Can this method now be applied generally in those large regions or states where the whole area has been completely surveyed and resurveyed? If such is the case it would offer an inexpensive method of eradication and at the same time a procedure convincing to the farmer and the public at large.

METHOD SUGGESTED

The following suggestions are made in order to stimulate a study and trial of such a method for the "clean-up" in barberry eradication. It is proposed that simultaneous surveys be made over certain areas of fairly uniform nature at a time in the year when the incipient local epidemics can be detected and before these local epidemics have had time to coalesce or to become general. If such surveys can be made with sufficient thoroughness and over sufficiently large areas it seems reasonable to assume that the remaining barberry bushes may be rapidly located. It also is possible that the findings may follow a descending order of the rust-producing potentialities of the bushes. That is, the larger plantings or bushes and those bushes in strategic positions for rust production may be expected to be among the first bushes found.

The suggested method would require a considerable force of men available in a given area on the same day or during a short period of days.

The time for making the surveys would need to be carefully selected for each area and should coincide with the occurrence of the local epidemics but should occur before the infection in the area is general. County agents and others interested in the rust problem probably could be enlisted for the work. The survey would include the collection of as many typical samples of small grains in as many localities as possible so as to cover thoroughly the whole area. No search need be made at this time for barberry bushes. The samples, marked accurately for locality, would be assembled at one central point, the rust percentage determined, and the areas represented would be mapped. Any areas consistently rusted could then be further investigated by the eradication forces for the location of possible bushes. The records for one year would be of great value in the succeeding year if rust-producing bushes escaped detection in the first year.

Perhaps the most puzzling detail of the suggested surveys would be the determination of the size of the area to be covered. If, for instance, the area included the southern half of the State of Minnesota with a corresponding area extended through the State of South Dakota, the field organization would have to be large and the survey could not be expected to be as complete as in a smaller area. Small local epidemics might easily be overlooked but, on the other hand, large sources of infection might perhaps be located and such areas could then be thoroughly studied. If the surveys were confined to a small group of counties the chances for the detection of small local epidemics would be better. The area covered, however, would be comparatively small and progress would be slow. An experimental test of both methods undoubtedly would yield valuable results for future use in barberry eradication.

The simultaneous surveys method is of course not new. It has been used in Blister Rust Eradication by Spaulding (U. S. D. A. Bull. 116, pp. 5), and others. It does not follow that it can certainly be applied to barberry eradication in all areas such as the great plains region. If, however, it can be used it may furnish a much needed means for the final eradication process, and it is of utmost importance that the barberry eradication be completed at the earliest possible moment.

RESULTS OF CLAY COUNTY SURVEYS

In order to test the possibilities as well as the numerous problems involved, simultaneous surveys were made on July 30, 1923, in Clay County, Minnesota, where black stem rust is a destructive disease of wheat and other small grains. At this time a fairly severe epidemic was general in northern Minnesota and North Dakota. Clay County measures 30 miles east and west by 36 miles north and south. It was separated into five areas as shown by dotted lines in figure 1. Each of these areas was surveyed on the same day by one crew of two experienced men. Each crew spent the whole day in a trip through its assigned area and collected typical samples

of rusted Marquis wheat (the standard wheat of this section) from as many fields as possible. A careful record of the location of each collection was made and notes were taken also on the topography, weeds, and other factors which might influence the severity of rust. The collectors also recorded their estimate of the percentage of rust in each field from which samples

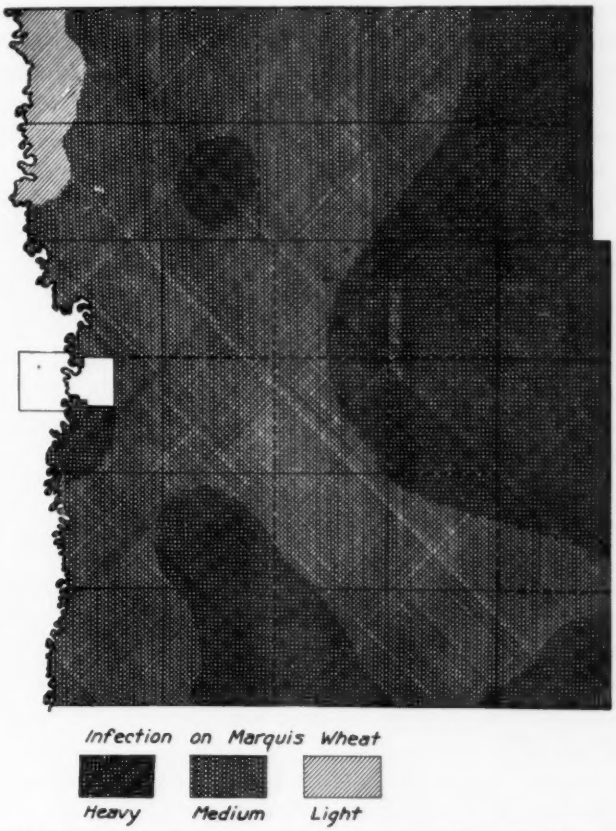

FIG. 1. Map of Clay County, Minn., showing relative severity of *Puccinia graminis tritici* on Marquis wheat, July 30, 1923.

were taken. The samples were brought to one central point and an estimate of each sample was made independently by each of three men who had had long experience in cereal-rust investigations. The estimates of these men, together with the field estimates of the collectors, were averaged and recorded as a basis for plotting the map (Fig. 1).

In all, 173 Marquis wheat fields were examined. The average mean percentage of stem rust was $39.86 \pm .91$ per cent. The rust estimates were divided into three classes, 0 to 20 per cent indicating light infection, 20 to 50 per cent moderate infection, and over 50 per cent, heavy infection. These classes were used in plotting the relative degrees of infection on the map.

It is obvious that there were consistent differences in the severity of rust in the different areas of the county. It was not the object of the surveys to determine the probable location of barberries, inasmuch as the rust infection had become general over the whole region and the grain was about to be cut. It was realized that such surveys for the location of barberries would have to be made at least several weeks earlier. It is a significant fact, however, that even at such a late date as the opening of the wheat harvest there are considerable and consistent differences in the rust severity in such an area as that examined where the conditions are as uniform as one could reasonably expect to find. Clay County lies in the Red River Valley and consists almost entirely of very flat prairie land with uniform soil. The types of farming, varieties grown, and other conditions also are quite uniform. While no correlation can safely be drawn in these surveys between rust infections and barberry locations, it is not impossible that presence of barberries might satisfactorily explain the rust differences, if all locations were known. The immediate point of interest is that with a well-developed and widespread general epidemic in an area of remarkably uniform conditions, simultaneous surveys showed consistent local differences in the rust attack. The results at least lend encouragement to the suggestion for simultaneous surveys in the location of barberries.

CEREAL AND GRASS INDICATORS

If simultaneous surveys of grain rust are to be undertaken for locating the straggling barberries, the cereal and grass hosts also should be carefully considered. Some results obtained in Minnesota during the summer of 1923 indicate that, at least in some years, winter rye may be a valuable indicator. The occurrence of the black stem rust on rye has been successfully used to locate barberries. Inasmuch as quack grass is so uniformly distributed and so abundant in the upper Mississippi Valley, there usually exists abundant teliospore inoculum of *Puccinia graminis secalis*. Moreover, the complication of windblown urediniospores from the South is possibly less in rye than in wheat as rye is grown only locally south of Minnesota and Wisconsin. The primary source of the rye rust in a given locality probably is more frequently confined to the barberry than is the case in wheat. If this be true, rye may be found a valuable indicator of barberry locations. The possible use of *Agropyron repens*, *Hordeum jubatum*, and other grasses as indicators ought also to be kept in mind in solving the problems of the possible use of the simultaneous surveys in locating scattered barberry bushes.

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RUST RESISTANCE IN TIMOTHY

H. D. Barker and H. K. Hayes[1,2]

With One Figure in the Text

INTRODUCTION

Hayes and Stakman (6)[3] have pointed out the desirability and possibility of developing varieties of timothy resistant to the timothy rust, *Puccinia graminis phleipratensis* (E. and H.) Stak. and Piem. But it is not known whether this rust form consists of several parasitic strains. Since the occurrence of such strains has been shown to be important in the problem of developing varieties of cereals resistant to stem rust, it seemed desirable to investigate this phase of the problem of developing resistant varieties of timothy. Furthermore, it is clear from the work of Biffen (2), Pole Evans (3), Hayes, Parker and Kurtzweil (5), Aamodt (1), and others, that the mode of inheritance of rust resistance is not the same in all cases. It is highly desirable, therefore, to obtain data on the mode of inheritance of resistance to timothy rust. The present paper, therefore, concerns itself largely with these phases of the problem.

MATERIALS AND METHODS

In 1916 a timothy nursery was started on University Farm, St. Paul. Eleven of the better Cornell selections and six of the better Minnesota selections were planted. Each selection was studied by the individual plant method in 1917 and data were taken on height of plant, erectness, length of head, number of tillers, yield of hay, and rust resistance. The results of this study for 1917 have been published (6).

The winter of 1917–18 was very severe and almost all the plants in the entire nursery winter-killed. In the fall of 1918, open pollinated seed was saved individually from several plants which survived. The seed was planted in the greenhouse in the spring of 1919 and 88 seedlings of each selection were transplanted in the field. They were planted in rows 3 feet apart, the plants being spaced 12 inches apart in the row. The single row plots were replicated twice. During three seasons data were obtained on yield, growth habit, etc.

[1] Published with the approval of the Director as Paper No. 475 of the Journal Series of the Minnesota Agricultural Experiment Station.

[2] The work was done as a part of a project on the production of disease-resistant varieties of field crops carried on jointly by the Section of Plant Pathology and the Section of Plant Breeding of the Department of Agriculture of the University of Minnesota.

[3] Reference by number to "Literature Cited," page 370.

In 1919 a heavy rust epidemic was induced by spraying with urediniospores collected near St. Paul, and the resistant plants in five of the most promising selections were increased in isolated plots. Several individual plants, with varying degrees of rust resistance, were selected, and 25 bulblets from each were propagated in the greenhouse. These clonal lines were used as possible differential hosts in determining the presence of biologic forms of timothy rust, and self-fertilized lines and crosses were used for studying the inheritance of certain characters.

Some of the effects of self-fertilization and the method of securing self-fertilized seed have been described previously by Hayes and Barker (4). Crosses were obtained in somewhat the same manner. Three plants of each of two clonal lines were separated from other timothy plants in the greenhouse by means of cheese cloth partitions. This was repeated in the field by placing the same number of plants in isolated groups in the small grain nursery at some distance from other timothy plants. Only those plants of the two clonal lines to be crossed were placed together. Since certain lines proved to be almost completely self sterile, it may be presumed for practical purposes that any seed set by such lines are the result of cross fertilization. The crosses studied are obtained from seed produced in the crossing plot from self sterile lines.

EXPERIMENTAL RESULTS

Table 1 presents data on the various lines, each of which is the progeny of a single open pollinated plant which survived the winter of 1917–18. A few lines, for example T 1 and T 11, were almost completely susceptible, while there were no lines which appeared to be completely resistant. There was some evidence that resistance might be a Mendelian dominant.

As previously described, a number of clonal lines were established by propagating individual plants vegetatively. For instance, clonal line T 30–30–9 was obtained from culture No. T 30 (a selection from Cornell No. 1777), row 30, plant No. 9.

Stakman and Piemeisel (9), Stakman and Levine (10, 11), and others, have demonstrated that *Puccinia graminis tritici* Erikss. and Henn. in reality consists of many biologic forms which differ in their pathogenicity for certain varieties of wheat. This has shown that the production of varieties of wheat resistant to stem rust is a complex problem. Stakman, Levine and Bailey (12) have shown that *P. graminis avenae* likewise consists of several forms or strains. In order to ascertain whether the same might be true of *P. graminis phleipratensis*, several clonal lines showing varying degrees of susceptibility to rust were used as possible differential hosts and inoculated with collections of timothy rust from various localities in the United States and Canada. For this purpose clonal lines have certain

TABLE 1.—*Nursery test of rust resistance in timothy in relation to other characters*

Culture No.	Source of seed; individual plant selected in fall of 1918 from	Total yield in grams 1919–1921 inclusive	Growth habit	Rust reaction in 1919 under epidemic conditions		
				Resistant	Intermediate	Susceptible
T 1	Minn. Selection from L. L. May and Company	17570	U to P[2]		1	88
T 2	do	14880	do	2		88
T 3	do	15357	U	3		87
T 4	do	16605	U to P	4		86
T 5	Minn. Selection from U. S. Dept.	17486	U	4		86
T 6	do	16193	U	4		86
T 7[1]	do	18093	U to P	20		60
T 8	do	14829	U	6	1	83
T 9	do	15231	U	10		70
T 10	do	15033	U	4		86
T 11	do	16290	U	1		89
T 12	Cornell No. 1620	16876	U to P	27		62
T 13	do	17231	U	46		34
T 14	do	18485	U to P	25		63
T 15	do	16250	U	14		74
T 16	do	17698	U to P	31		58
T 17[1]	do	18596	U to P	61		28
T 18	Cornell No. 1630	17483	P	62		27
T 19	do	15288	U	26		62
T 20	do	15708	U to P	48	1	38
T 21[1]	Cornell No. 1635	18527	U to P	58		24
T 22	Cornell No. 1676	17900	P to U	69		20
T 23	Cornell No. 1671	16982	U to P	61		29
T 24	do	17327	U to P	60		28
T 25	Cornell No. 1715	15680	U to P	31		56
T 26	Cornell No. 1743	17276	U to P	57		32
T 27	do	20082	P to U	55		32
T 28[1]	Cornell No. 1777	20428	U to P	83		17
T 29	do	17736	U to P	28		60
T 30	do	18545	P to U	47		33
T 31	Cornell No. 3230	17129	U to P	50		37
T 32	do	16692	U to P	48		31
T 33[1]	N. King Co. Sterling Commer.	16837	U to P	24		65
T 34	Cornell No. 1611	6359	U	74		8

[1] Rust resistant plants in these selections were given Minnesota numbers and increased in isolated plats for further tests.

[2] U = upright; P = procumbent; U to P = approaching upright; P to U = approaching procumbent.

advantages and certain disadvantages. Vegetative propagation eliminates the possibility of variable results due to natural crossing or mechanical mixture of seed. This is perhaps more than offset by the variable growth conditions at the time of inoculation. Seedlings may be inoculated at approximately the same stage of growth; it is more difficult to get plants

of a clonal line of timothy at the same stage of growth. The vegetative condition and vigor of the plant modified the character of the uredinia produced to a marked degree. In addition to this, the rust classes as recognized by Stakman and Levine (10) for stem rust of wheat are not so sharply defined on timothy. In no case, however, did a resistant plant become completely susceptible, nor did the susceptible ones become resistant. The results presented in table 2 are based on the average type of infection for a given strain of rust on the clonal line concerned. Certain collections of rust were lost, due to adverse conditions at the time of transfer, before they could be tried on all clonal lines. In these cases, not all of the observations are based on repeated inoculations. It was thought that since these, on the basis of the observations made, were in general conformity with those collections upon which more complete data were obtained, they might all be presented for whatever value they may possess.

TABLE 2.—*Inoculation experiments to determine the presence of biologic forms of Puccinia graminis phleipratensis (E. and H.) Stak. and Piem.*

Rust collection[1] from	Type of rust reaction[2] on															
	T 1–1–26	T 30–30–9	T 30–30–21	T 30–63–23	T 31–31–5	T 31–31–32	T 31–64–1	T 31–97–11	T 31–97–18	T 32–32–26	T 32–32–29	T 32–32–30	T 32–65–14	T 32–65–29	T 32–98–27	T 32–98–27
Edmonton, Alta.	4	1	2	2	2	2	4	2	2	2	1	2	2	2	2	1
Courtenay, B. C.					1							2				
Lafayette, Ind.	4			2	2				2	3	2	2	2	2	2	
Ithaca, N. Y.	4	1	3	2	1	2	3	2	2	2	1	1	2	2	2	2
Loweville, N. Y.	4				2				1			2			2	
Fens, Minn.	4	2	2	3	2	2			1	2	2	1	2	1		3
Hopkins, Minn.	4	2	2	2	2					1	1	2	2		2	2
St. Paul, Minn.	4	2	2	2	2	2	3	2	2	2	2	2	2	2	1	2
Field test, 1919 (St. Paul)	S	R	R	R	R	R	R	R	R	R	R	R	R	R	R	R

[1] Rust collections from Courtenay and from Edmonton were furnished by Dr. E. C. Stakman, from Lafayette by Dr. E. B. Mains, from Ithaca and Loweville by Dr. R. S. Kirby.

[2] The symbols used to express types of reaction are adopted from those used by Stakman and Levine (10). Since, however, hypersensitiveness and chlorosis are not so sharply defined in timothy as in wheat, more emphasis is placed on size of uredinia. In the field tests the plants are listed as susceptible or resistant.

From table 2 it appears probable that, on the differential hosts inoculated, the various collections of rust are practically identical. While this test does not prove that biologic specialization does not occur in *P. graminis*

phleipratensis, it indicates that these clonal lines probably would be highly resistant in widely separate localities.

More extensive tests should be made for the presence of biologic specialization in timothy rust. If none is found in this form, it may be quite significant with respect to the origin of biologic forms, because this rust apparently cannot produce aecia on barberry (7, 8).

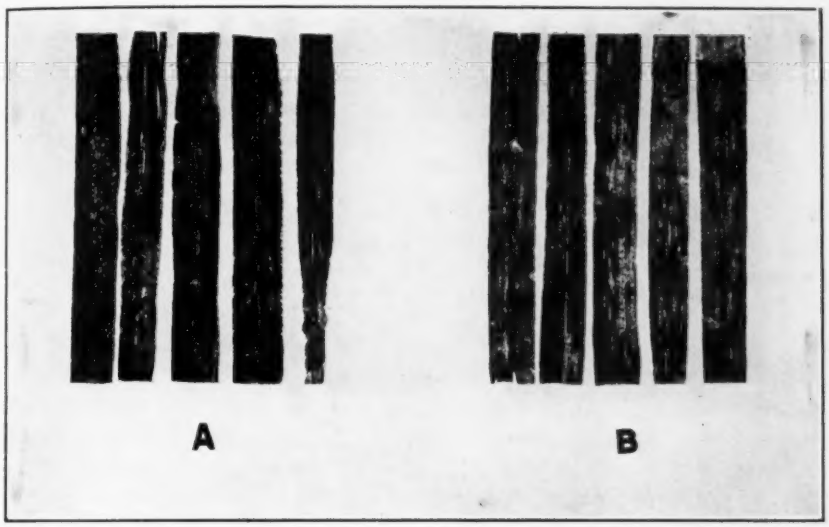

FIG. 1. Illustrations of rust-resistance and rust-susceptibility of timothy plants:
A—Various types of infection which were recorded as susceptible.
B—Various types of infection which were recorded as resistant.

Note that very sharp hypersensitive areas do not appear in timothy. Resistant plants give small pustules which are not confluent. Marked chlorosis is usually, but not always, associated with resistance. This chlorosis may approach distinct hypersensitiveness.

The seed of various self-fertilized clonal lines and of crosses between certain of these clones were secured by the plan described under Materials and Methods. The selections were planted in the greenhouse in the spring of 1922 and inoculated in the seedling stage with urediniospores collected near St. Paul. Ten days after inoculation, notes were taken on each seedling plant. The character of the rust reaction upon which these were classified as resistant, or susceptible, are illustrated in figure 1. The results of the inoculations are summarized in table 3:

The results presented in table 3 indicate quite clearly that the inheritance of rust resistance is here dependent upon a single pair of genetic factors, giving approximately three resistant plants to one susceptible. Resistance is clearly dominant, because, although there was considerable

TABLE 3.—*Inheritance of rust resistance in timothy on the basis of inoculation results obtained in the greenhouse in the spring of 1922*

Group No.	Selection or cross	Source of seed	No. of plants			Expected ratio on the basis of						Observed ratio	P. E.	Probability
			Total	R	S	3 R to 1 S		1 R to 1 S		R	S	R : S		
1	T 30–30– 9	G[1]	140	118	22	105	35					3.37 : 0.63	0.10	1 : 78.37
2	do	F	154	105	49	115.5	38.5					2.74 : 1.26	0.09	1 : 18.80
3	T 30–30–21	G	27	23	4	20.25	6.75					3.41 : 0.59	0.22	1 : 4.64
4	do	F	153	92	61	114.75	38.25					2.41 : 1.59	0.09	1 : 19230.00
								76.5	76.5			1.20 : 0.80	0.05	1 : 142.26
5	T 30–63–23	G	75	63	12	56.25	18.75					3.36 : 0.64	0.14	1 : 11.58
6	T 31–31– 5	G	90	79	11	67.5	22.5					3.48 : 0.52	0.12	1 : 142.26
7	T 31–64– 1	G	60	46	14	45	15					3.07 : 0.93	0.14	1 : 1
8	do	F	158	105	53	118.5	39.5					2.66 : 1.34	0.09	1 : 64.79
9	T 31–97–11	G	180	134	46	135	45					2.98 : 1.02	0.08	1 : 1
10	do	F	144	107	37	108	36			59		2.97 : 1.03	0.10	1 : 1
11	T 31–97–18	G	59	59						59				
12	T 32–32–30	F	27	17	8	20.25	6.75					2.82 : 1.18	0.22	1 : 1
13	T 32–65–29	G	3	3						3				
14	T 32–98–24	G	16	11	5	12	4					2.75 : 1.25	0.29	1 : 1
15	T 32–98–27	G	18	18						18				
16	T 1– 1–26	G	2								2			
17	T 1– 1–26 x T 32–32–30	F	196	100	96			98	98			1.02 : 0.98	0.05	1 : 1
18	T 32–65–14 x T 32–32–30	F	47	38	9	35.25	11.75					3.24 : 0.76	0.17	1 : 1.9
19[2]	N. K. Sterling		144	21	133									
20[3]	T 7 Increase	F	53	41	12	39.25	13.25					3.03 : 0.97	0.16	1 : 1
21[3]	T 17 do	F	64	51	13	48	16					3.39 : 0.81	0.15	1 : 1.63
22[3]	T 21 do	F	83	58	25	62.25	20.75					2.88 : 1.12	0.13	1 : 1
23[3]	T 28 do	F	77	61	17	57.75	19.25					3.10 : 0.90	0.13	1 : 4
Totals for 3 : 1 ratio			1445	1057	338	1046.25	348.75					3.03 : 0.97	0.03	1 : 1
Totals for 1 : 1 ratio			196	100	96			98	98			1.02 : 0.98	0.05	1 : 1

[1] G = seed produced in the greenhouse, cheese cloth partitions. F = isolated field plots.
[2] Commercial seed lot. (Northrup, King and Co., "Sterling") as check.

variation in the resistant types, there was little approach to an intermediate condition (See figure 1).

Groups 1 to 16, inclusive, are each the progeny of clonal lines, which have been selfed in the greenhouse or in the field, according to the methods described. Where seed was obtained from a clonal line by growing vegetatively propagated plants in an isolated plot in the small grain nursery, and also from the same line by being self-fertilized within cheese cloth partitioned booths in the greenhouse, the results are not in general different. There is one exception, however, in group 4. The ratio of resistant to susceptible is more nearly 1:1 than 3:1, possibly indicating that this clone was not sufficiently isolated in the field and that the seed produced was almost completely the result of cross pollination with susceptible unselected plants—some escaped, or "wild" plants were evidently nearer this plot than was realized. All of the other "self-fertilized" clones conform about as closely to expected results as might be anticipated upon the basis of the numbers concerned in each case. The crosses, groups 17 and 18, fall well within the expectation.

Groups 20 to 25, inclusive, are from the increase plots as described in the foot-note 1 of table 1. Each of these increase plots consists of several resistant plants from the selection number indicated. Consequently, the seed produced is perhaps in part the result of self-fertilization and in part inter-fertilization of the resistant plants of this selection. It is interesting to note that the reaction of the seedlings of each of these groups approximate very closely a 3:1 ratio.

On the basis of the tests recorded in part in table 3, further selections for desirable types of timothy homozygous for rust resistance, and possessing as much self-fertility as possible, is being continued by the Minnesota Experiment Station.

SUMMARY

1. Preliminary breeding tests of various selections of timothy for rust resistance indicated that certain selections were quite resistant to rust. Some selections consisted almost entirely of resistant plants, others possessed few, or no resistant plants. The large number of resistant plants in certain selections suggested that resistance might be a Mendelian dominant.

2. On the basis of the field test, further selections were made. This included several clonal lines from which self-fertilized seed was obtained and certain crosses were made.

3. Various clonal lines were inoculated with collections of timothy rust from different localities in the United States and Canada. No definite

evidence of biologic specialization of *Puccinia graminis phleipratensis* was found, although more experiments should be made.

4. The fact that the resistant clonal lines of timothy were resistant to rust collected from widely separated localities lends encouragement to the production of rust-resistant varieties.

5. If no biologic forms of *P. graminis phleipratensis* exist, the fact may be of considerable significance in connection with the origin of biologic forms.

6. Inoculation experiments on seedlings produced from self-fertilized clonal lines, and from crosses between clonal lines, indicate that resistance or susceptibility in the selections of timothy studied is dependent upon a single differential factor pair. Resistance appears to be a dominant, and a close approximation to a 3:1 ratio was obtained in the progeny of self-fertilized resistant plants.

7. The facts presented in this paper indicate that the production of varieties of timothy, which will be resistant to stem rust in different regions, may be accomplished rather easily.

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WITCHES' BROOM OF POTATOES IN THE NORTHWEST

CHAS. W. HUNGERFORD AND B. F. DANA[1]

WITH PLATE XXV AND FOUR FIGURES IN THE TEXT

INTRODUCTION

During the summer of 1923, an unusual disease of potatoes has been reported throughout the Pacific Northwest by various plant pathologists and others concerned with the certification of seed potatoes. The disease, which has been noted on all the commercial varieties grown in this section, is apparently very similar, if not identical with, the one figured and very briefly described by Bisby and Tolaas (1) as occurring in Minnesota. They have called the disease witches' broom and, as the name seems appropriate for the disease which we are describing, we have retained it.

The meager amount of information available concerning the trouble and its widespread occurrence the past season has made it seem desirable to prepare a preliminary note giving the results of observations made by the authors and others. The data given are largely observational. Experimental work to determine the nature of the disease and its possible relation to other diseases of the potato has been started. The data herein presented include not only observations made by the writers, but also notes relative to the occurrence of the trouble furnished by Prof. H. E. Morris of the Montana Agricultural Experiment Station, Mr. E. R. Bennett of the Idaho Agricultural Extension Division, and Mr. J. E. Currey of the Washington State Department of Agriculture.

The symptoms of the disease differ in many respects from those of any disease with which the authors are familiar. Indeed, the appearance of the diseased plants is so striking that growers have readily recognized it as a separate disease. However, as it has not yet been possible to complete careful experimental work and as the cause has not been determined, we do not claim that the disease may not be an unusual manifestation of some known trouble or an unusual combination of known troubles.

OCCURENCE AND DISTRIBUTION

Witches' broom has been given very limited attention by writers discussing potato diseases. Whipple (8) pictures a "yellow top degenerate" which is apparently identical with one phase of witches' broom. He further

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pictures and describes the progeny of such a hill which is similar to progeny of witches' broom plants developed by the writers. Tuber development described by Whipple for the "yellow top degenerate" is very characteristic of witches' broom and leaves little question but that the two diseases are identical.

Bisby and Tolaas (1) barely mention witches' broom of the potato as of rare occurrence in Minnesota and suggest that it may be similar to spindling sprout which is said to be rather uncommon with them. These writers picture this disease and also the spindling sprout, making it evident that the witches' broom they studied was the same as that occurring in the Northwest.

Cutler and Sanford (4) and Coons and Kotila (3) also consider witches' broom as associated with spindling sprout. Professor Cutler, in a letter dated January 24, 1924, states that witches' broom was not common in his district. Coons and Kotila do not consider the disease of commercial importance as it eliminates itself by reduction in size of tubers.

This same disease was observed by Dr. F. D. Heald in 1917 at Pullman, Washington, but at that time he did not differentiate between it and the effects of Rhizoctonia which was abundant on the undergrown parts of the affected plants. No special study of the disease was made and no further occurrences of the trouble in Washington were noted until the season of 1923.

These meager reports are sufficient to give basis for the belief that this disease has occurred occasionally in seed stocks and was considered a manifestation of "running out" or was confused with other diseases. Study has probaby been limited because of the fact that diseased hills usually produce very few tubers and self-extinction of severely diseased stocks is sudden and complete under ordinary conditions.

During the summer of 1923 the disease occurred promiscuously throughout the Northwest in certified and non-certified seed stocks. Growers and inspection officials have been interested in the disease because of its distinctive symptoms. Excellent opportunity was offered for study by the appearance of the disease in experimental plots at the Washington and Idaho Experiment Stations. At both stations the disease has occurred in the field and greenhouse-grown selections used for the study of the leaf roll and mosaic diseases. The seed stocks used for these studies have been under observation for several years without any of the disease being observed.

SYMPTOMS OF WITCHES' BROOM

We have noted two types of symptoms which in the light of present data we suggest may be primary and secondary symptoms of witches' broom. The primary symptoms described are those appearing during the

growing season and evidently developing subsequent to the infection of a normal plant with the disease. Secondary symptoms, or those appearing in plants produced from diseased seed, differ considerably from the primary symptoms and will be described separately.

Due to the fact that the secondary symptoms were noted first, we have chosen to describe them before we take up the primary symptoms.

FIG. 1. Extreme witches' broom development on a Netted Gem potato plant.

Secondary Symptoms from Diseased Tubers

The characteristic bushy appearance of plants from infected seed has given rise to the name witches' broom. Typical diseased plants are shown in figure 1, and plate XXV, fig. 1. As will be noted, every eye on the seed tuber must have given rise to a stalk and these in turn produced side shoots at every available bud. One of the most constant symptoms of this disease in all stages is the tendency for all buds, including those usually latent on a normal plant, to push into growth.

The symptoms associated with the disease were studied in detail in diseased plants found in the experimental plots at both the Idaho and Washington Agricultural Experiment Stations, and in various commercial fields throughout the two states. Opportunity was also offered to study the oc-

currence of these symptoms in some volunteer potatoes on the Washington Experiment Station. Figure 1 is a photograph of a diseased volunteer plant. As may be noted in the figure, the nodes are somewhat enlarged. Leaf-petioles and stems are smooth and rounded having none of the angular conformation of a normal potato plant. Leaf-petioles tend to be elongated and the leaflets narrow and spaced some distance apart. The leaves, stems and flower clusters assume an upright position giving a very characteristic appearance to the plant. The production of flower clusters and the setting of seed balls is sometimes emphasized in such plants. The affected volunteer plants were of large size and nearly as dark green in color as normal plants. The plants withered and died earlier than other vounteer plants in the same field.

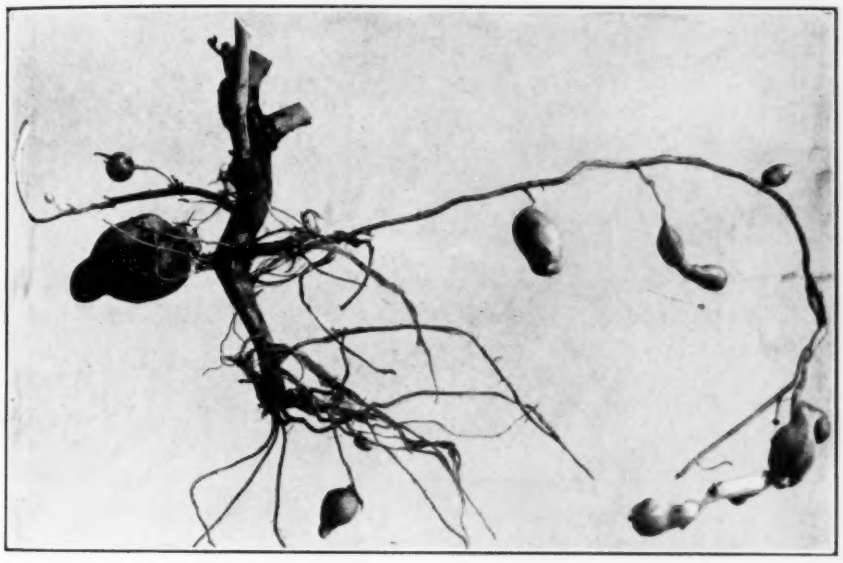

FIG. 2. Prolonged stolon development with formation of successive tubers on a Netted Gem potato plant.

The witches' broom plants developing in the experimental plots, although of the same variety, did not attain the size of the volunteer plants. The foliage was not so luxuriant and the color was distinctly yellowish. Plate XXV, fig. 5 shows plants of this character. They are similar to the plants pictured and described by Whipple (8) as "yellow top degenerates." The symptoms, otherwise, were similar to those described for the volunteer plants. All parts, however, were reduced in dimensions and the leaflets were somewhat crinkled in appearance. The tendency to bloom and set seed balls was

often pronounced in plants of this character. This type of plant was observed in certified and non-certified seed stocks in which the disease had not been recognized the previous season. Essentially the same symptoms were exhibited under irrigated as under dry-land conditions and in some fields were found in as high as twenty-five per cent of the plants. Plants of this type retained their upright habit of growth until the period of rapid decline which was long before the normal ripening period for the field.

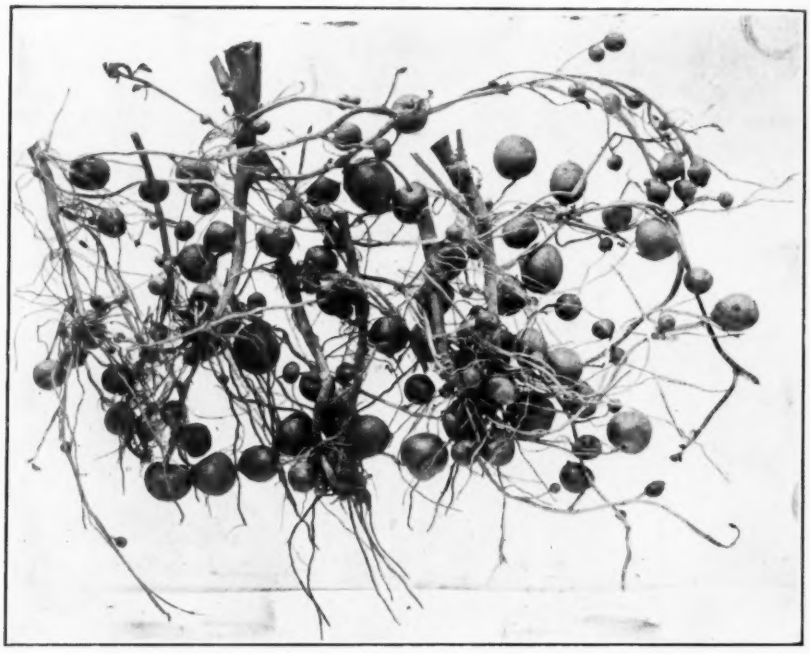

FIG. 3. Bliss Triumph potato showing excessive number of tubers produced on some diseased plants.

The outstanding features of plants of this character were the yellowish color, and the increased number of shoots making appropriate the term "witches' broom."

The production of aerial tubers took place on witches' broom plants of the Bliss Triumph variety in experimental plots at the Idaho Station and were also noted many times on this variety in commercial fields. Plate XXV, fig. 1 shows one of these plants with the leafy aerial tubers on the lower half of the stems. The other characters were similar to witches' broom described above.

Aside from the symptoms on the foliage, the tubers in diseased hills also present abnormalities which are very striking. One notices first, that

the number of potatoes in diseased hills usually very greatly outnumbers those in healthy hills. As many as 200 tubers have been counted in a single diseased hill. Figure 3 illustrates this condition. As shown by the photograph, these tubers are usually very small, varying in size from about as large as a pea to the size of a walnut. Some of these tubers develop net

FIG. 4. Leafy tubers produced in the greenhouse on a Netted Gem potato plant.

necrosis similar to that found in leaf roll diseased stock, although this condition is not always present. One condition which is very characteristic of the disease wherever it has been noted is the fact that the various buds of all the eyes of the tubers have a tendency very early in their development to start growth. Aerial tubers on diseased plants quite uniformly produce leafy growths at the eyes. Tubers produced under ground have

been found with half a dozen stolons growing out of the eye end. These stolons often produced more tubers which sprout in turn forming a series of small tubers on the stolons in a manner resembling a chain of beads. See figure 2. Many of these elongated stolons later reach the surface of the ground and develop leafy-shoots coming up around the main plant thus covering the ground with a bushy growth several feet across. The appearance of such a plant is very striking. A farmer once remarked to one of the authors that these potatoes must have become crossed with quack grass. Nearly all of the witches' broom plants observed showed this development to some degree. In many cases the original plant died, but the growth of the surrounding shoots continued until killed by frost. Tubers produced by this type of plants were usually formed near the surface of the soil and were either leafy or produced short shoots at the normal position of the eyes. Such tubers did not mature by digging time and many shriveled in storage.

The production of stolons from tubers before the end of the season has been observed to follow conditions where a period of abundant moisture and lower temperature has followed a period of high temperatures and scarcity of moisture. In Eastern Washington and Northern Idaho such a condition prevailed in 1919. On the advent of moisture following the drought, the tubers produced stolons and shoots which pushed up through the soil. A similar condition has been described by Clinton (2) in Connecticut. It is felt by the writers that this condition is not related to witches' broom because seed stock from these fields produced normal plants the following year and the symptoms were by no means so extreme in any case as in the witches' broom development.

That witches' broom is transmitted by the tubers was conclusively shown in some tuber unit plantings made at Moscow, Idaho, in 1923. Plate XXV, fig. 5 shows three tuber units grown from some Bliss Triumph stock which was carefully rogued in 1922. The four hills in the lower righthand corner of the picture are from a diseased tuber, while those in the rear and to the left are healthy. Whipple (8) also calls attention to the fact that his "yellow top degenerate" always appeared in tuber unit groups.

The progeny of seriously diseased witches' broom plants, when grown in the greenhouse, often have a spindling sprout type of growth. One to several thin shoots develop from each bud on the tuber. Growth continues to be retarded throughout the development of the plant under greenhouse conditions. Small aerial tubers are common on such plants while practically no normal tuber production takes place. Figure 4 shows leaf character and aerial tuber production on greenhouse-grown progeny of witches' broom plants.

The spindling sprout figured by Stewart and Sirrine (7) and by Stakman and Tolass (6) does not appear like that described above because of growth taking place from only a few buds. Bisby and Tolaas (1), although showing the same cut of spindling sprout as Stakman and Tolaas (6), suggest that it may be related to witches' broom. Cutler and Sanford (4) and Coons and Kotila (3) in their considerations of spindling sprout and witches' broom, respectively, describe a large number of spindling sprouts arising from the seed piece. This is also characteristic of the spindling sprout related to witches' broom as worked with by the authors. Whipple (8) connected this type of spindling sprout with the "yellow top degenerate." The spindling sprout figured by McKay (5) is identical in habit with that studied by the writers.

With the exception of Bisby and Tolaas (1) and Coons and Kotila (3), the workers mentioned above have not noted relationship of spindling sprout to any other symptoms developing on the plants. From the preliminary work accomplished we believe that spindling sprout often accompanies extreme deterioration or degeneration from the witches' broom disease. We also recognize the fact that other types of spindling sprout may have entirely different causal relations.

Primary Symptoms Appearing Late in the Season

All of the symptoms described above have been those appearing early in the season from apparently diseased sets. Later in the season what is apparently the same disease appeared on plants previously showing none of these symptoms. In one plot of Bliss Triumph potatoes, grown at Moscow, Idaho, on the Experiment Station Farm, five per cent of the plants were rogued out early in the season on account of witches' broom. Soon after August first it was noted that a considerable number of plants which had previously apparently been healthy were developing symptoms of the trouble. The first indication was a tendency for the newer leaves at the tips of the branches to become slightly rolled, lighter green with a reddish yellow margin and with an upright habit of growth. In a short time these symptoms became more marked so that affected plants could be noted at a considerable distance. The tendency for proliferation, described above, developed also in these plants, expressing itself in numerous shoots developing in the axils of leaves at the tips of the branches and also in the sprouting of the eyes in the new tubers formed underground. When these hills were dug, there were one or two normal well developed tubers which had apparently been formed before the plant became affected. Also there were many small tubers in the beadlike formation described above, which had evidently been formed after the plant became diseased. Sixteen per cent of the plants in the plot mentioned above were rogued out during

the later part of the season. Table 1 gives in percentage the number of plants removed from each plot both before and after August first. Those rogued before August first were evidently from diseased sets, while those rogued after August first showed the primary symptoms described above.

TABLE 1.—*Percentage of witches' broom plants rogued from certain potato plots grown at Moscow, Idaho*

No. of plot	Variety	Per cent rogued before Aug. 1st	Per cent rogued after Aug. 1st
19	Bliss Triumph	5	16.0
20	Bliss Triumph	10	8.0
12	Idaho Rural	0	6.2
13	Idaho Rural	0	3.5
14	Idaho Rural	0	3.2
15	Idaho Rural	0	4.0

Although we have no experimental evidence that this secondary development was due to the same cause as the trouble which appeared earlier in the season, the symptoms were so nearly similar that we were led to believe this to be the case. It was noted that the condition which developed later in the season many times occurred in plants immediately adjacent to the missing hills which had been rogued out earlier in the season.

Plate XXV, figure 3, shows a plant with these early symptoms, showing particularly in the leaves at the tips of the shoots. The leaflets on the shoots were rolled and in the Green Mountain variety the edges of these leaves were light yellowish in color, but with the Bliss Triumph a reddish color developed on the edges of affected leaflets. This was also true of the Cobbler and became more pronounced toward the end of the season. Affected plants were about normal in size. A more advanced stage is shown in Plate XXV, figure 4. Lower leaves were normal in size and texture, but the effect on the top was becoming pronounced. In the Netted Gem such plants in the field were conspicuous because of their yellow color and upright habit and tendency to bloom and set seed balls.

The primary stage of the witches' broom of potato has not been described in the literature available to the writers. Symptoms similar to these have in the past been ascribed to the attacks of the Rhizoctonia fungus, and may also easily be confused with the primary symptoms of leaf roll. In fact it may in some cases require the actual study of progeny to determine the difference between the primary stage of leaf-roll and witches' broom. The effect upon tuber formation seems to be a characteristic of the witches' broom disease only.

Nature of Witches' Broom

Sufficient data has not been gathered upon which to base a positive statement as to the cause of witches' broom. For the present we can only describe the conditions under which the disease has appeared. These data may indicate the factors responsible for or influencing the disease and from which a theory as to the cause of the disease may be formulated. Such a theory will be useful in correlating further data and in giving direction to such experimental work as is necessary to furnish proof of the cause of the disease.

During the past season witches' broom has occurred under a wide variety of conditions. It was manifest in considerable amounts in the fertile Skagit River Valley of western Washington. No more ideal conditions could be desired for the growing of potatoes than were to be found in this valley. The disease was likewise observed under very favorable growing conditions in the Willamette River Valley of western Oregon, and in the Snake River Valley of southern Idaho. The appearance of the disease under such favorable conditions would tend to show that lack of moisture or plant food were not responsible for its appearance or severity. On the other hand, the disease was observed in northern Idaho and in eastern Washington, under very adverse conditions as well as under moderately favorable conditions for potato culture. Some very severe cases occurred on thin soil where there was a positive shortage of moisture. Under such conditions the plants succumbed early, but the symptoms were essentially the same as those occurring on plants in good soil and well supplied with moisture.

Diseased Netted Gem stock divided and planted under irrigation in central Washington and under dry land culture in eastern Washington produced plants having similar symptoms. In connection with a study of potato mosaic and leaf roll being carried on at the Idaho Experiment Station, the effect of environmental conditions upon the development of these diseases is being tested by planting the same lots of seed in various localities. In 1923 a certain lot of Bliss Triumph seed was divided and grown at Moscow, Coeur d'Alene, and Winchester under non-irrigated conditions, and at Ashton and Parma under irrigation. Witches' broom developed at all of these places. The amount of infection early in the season was practically the same at all five places. Our data seem extensive enough to warrant the conclusion that environmental factors during the growing season do not control the appearance of witches' broom.

The disease was noted in fields planted both early and late, and it was also observed in a field of volunteer potatoes. Periodic plantings were made every two weeks from April to July, at Pullman and Prosser, Washington, of stock which developed about three per cent of the disease; no appre-

ciable relation was noted in these plots between time of planting and the development of the disease. From a study of the disease throughout the season we may say that seasonal variation does not seem to greatly influence the percentage of disease appearing in seed stocks but may influence the size and longevity of the affected plant.

The question naturally arises whether improper storage conditions may not be a possible factor in the production of witches' broom. Evidence at hand does not warrant such a conclusion. Reference has already been made to the occurrence of the disease in a field of volunteer potatoes. The disease has also been observed in many different unrelated stocks kept in common storage for the winter. Specially selected stock at both the Idaho and Washington Experiment Stations kept in good commercial storage during the winter showed an appreciable amount of the disease in the resultant crops. Over the region where this disease has appeared there must of necessity have been a wide variation in the storage conditions under which the various stocks were kept. The appearance of the disease under such a variety of conditions would tend to show that storage conditions do not cause the disease. This point is strengthened by the occurrence of the disease in selections planted in the greenhouse after only a short rest period following the harvest.

The transmission of witches' broom has not been accomplished under controlled conditions. Enough evidence has accumulated, we believe, to prove that the disease is carried by tubers. The same seed stock planted at the same time in widely separated places and otherwise handled the same has shown the disease in practically the same percentage and severity. The same hill selections planted in the greenhouse and portions also planted in the field show like infections of the disease. Progeny of witches' broom selected from the field have shown typical symptoms when grown in the greenhouse.

The dissemination of witches' broom in the field was indicated on the Idaho Station by the results secured in the test plots mentioned above. Here there seemed to be evidence that infection took place during the growing season. The appearance of the disease in partly grown plants which develop typical symptoms in those portions developing thereafter would indicate that the disease is spread during the growing season. Investigational work is in progress which it is hoped will show how the disease is spread and also furnish a basis for conclusions as to the cause of the malady.

The witches' broom disease has some symptoms in common with several other disease, among which may be mentioned Rhizoctonia, leaf roll, and spindle tuber. The Rhizoctonia fungus has not been constantly associated with the disease and furthermore, it has been shown that witches' broom is

Fig. 1. Witches' broom with production of aerial tubers on Bliss Triumph plant. Fig. 2. Leafy shoots developing from elongated stolons on Netted Gem plant. Fig. 3. Symptoms of recent infection on Green Mountain plant. (Photograph by J. E. Currey.) Fig. 4. Well developed symptoms on the top of Netted Gem plant. Fig. 5. Three tuber units of Bliss Triumph variety, one of which is affected with witches' broom.

constantly transmitted by seed tubers. The symptoms common to witches' broom and leaf-roll are: the slight rolling of the upper leaves on newly infected plants, the spindle sprout symptoms, and the net necrosis sometimes developing in the tubers. Aside from the fact that the type of leaf roll and the spindle sprout described above for witches' broom are radically different from the same manifestations of the leaf-roll disease, the other symptoms which we have discussed have not, to the knowledge of the writers, been associated with leaf roll. The above statement will also apply in a comparison of witches' broom and the spindle tuber disease. The symptoms characterizing witches' broom have not yet been mentioned in descriptions of the spindle tuber disease available to the writers.

In view of the facts set forth in this paper, we believe that we are justified in considering witches' broom a distinct disease of the potato. The cause of this disease, which was widely distributed during 1923 throughout the Pacific Northwest, has not been found. Work is progressing along several lines and it is hoped that more concerning the nature and cause can be given in a later paper.

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EQUIPMENT AND METHODS FOR STUDYING THE RELATION OF SOIL TEMPERATURE TO DISEASES IN PLANTS.

R. W. LEUKEL

WITH FIVE FIGURES IN THE TEXT

INTRODUCTION

Soil temperature is receiving increasing recognition as an important factor influencing the development of plant diseases especially soil-borne and seed-borne diseases and those attacking the underground parts of plants.

The study of soil temperature up to 1921 has been admirably summarized by Jones[1] and a brief description given of the Wisconsin tank now used in the Department of Plant Pathology at the University of Wisconsin and in a number of other institutions in this country.

The writer fortunately had the opportunity of using this apparatus from 1920 to 1922 in connection with certain cereal-disease studies conducted cooperatively by the Office of Cereal Investigations, Bureau of Plant Industry, and the University of Wisconsin. In 1922 the writer was transferred to Washington, D. C., where equipment for the control of soil temperature was installed in the cereal-disease greenhouse at Arlington Experiment Farm.[2] In the installation several difficulties were encountered. The supply of water at Arlington Experiment Farm is limited and its temperature comparatively high so that special means for obtaining low soil temperatures had to be devised. High pressure steam is not constantly available and when needed had to be supplied from a small boiler in the greenhouse basement. All electrical equipment had to be adapted to a 220-volt 25-cycle alternating current.

In this paper is presented a detailed description of the various items of equipment together with their operation and the methods employed at Arlington Experiment Farm in the study of the relation of soil temperature to certain cereal diseases. It is thought that this may be of interest to those contemplating the installation and operation of similar equipment.

The actual results of the experiments will appear in a later series of papers.

[1] Jones, L. R. Experimental work on the relation of soil temperature to disease in plants. Trans. Wis. Acad. Sci., Arts and Letters **20**: 433–459, *pl. 33–37*. 1921.

[2] Much of this work was done under the general direction of Dr. A. G. Johnson whose helpful advice and suggestions are gratefully acknowledged.

THE TEMPERATURE-CONTROL TANK AND ITS EQUIPMENT

The Tank

The tank (Fig. 1), which is copied after the one devised at the Department of Plant Pathology of the University of Wisconsin, is a rectangular structure 21 inches wide, 39 inches long, and 28 inches deep on the inside. The lining is of 24-gauge galvanized iron. The upper three inches of metal are turned out at right angles to the sides to lap over the upper edges of the outer wooden wall. All seams are well soldered and made water tight.

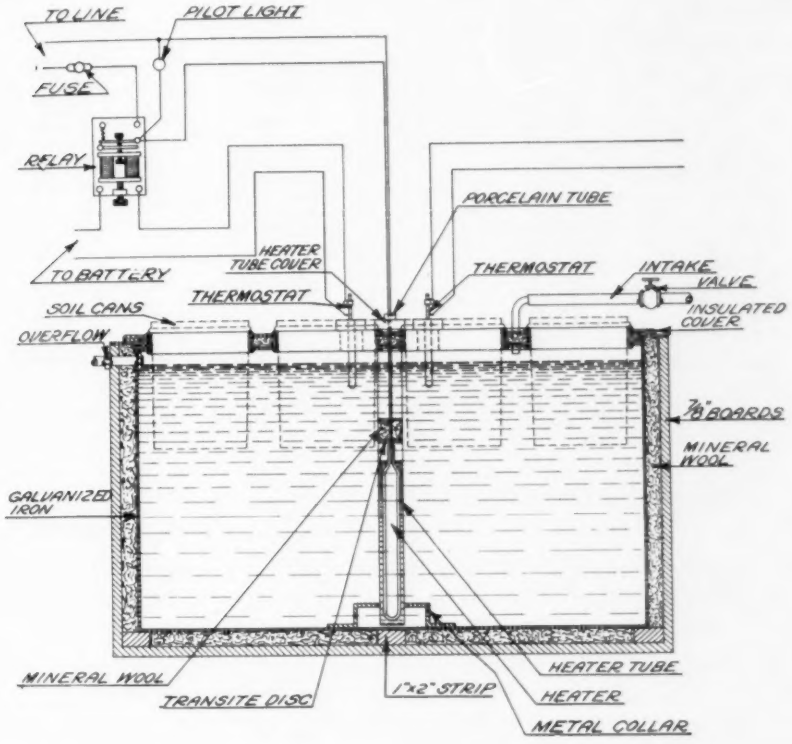

FIG. 1. Soil temperature-control tank and part of its accessory equipment for maintaining constant high, low or medium soil temperatures. The thermostat on the right regulates the inflow of cold water and the one on the left controls the heater.

The outer wall is made of seven-eighths-inch cypress boards nailed to 2″ x 4″ material at the corners. The inside dimensions of this outer wooden unit are about 3 inches greater than those of the metal lining. The space between the wood and the metal is packed with mineral wool. A half-inch overflow pipe near the top of one end is held in place by

lock nuts, and leads to a return pipe through which the water flows back to the ice-water tank, as described later.

The Cover

The cover (Fig. 2) consists of a top and bottom of galvanized iron with a solid piece of half-inch "flax linum" between. The lower sheet of metal is bent over the edges of the insulation and joined to the upper sheet of metal to form a flange which rests on the metal edges of the tank.

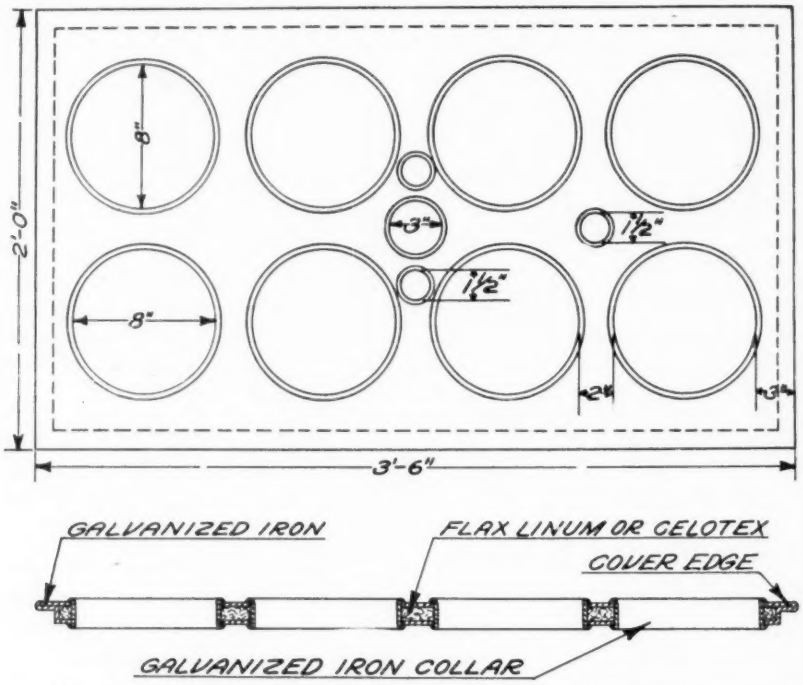

FIG. 2. Diagram of the cover for the soil temperature-control tank showing the arrangement of the openings. The cross section shows its construction.

The 8-inch openings for soil cans are placed about three inches from the edge. The three-inch opening in the center is for the heater tube. On each side of this 3-inch opening is a 1½-inch opening, one for the thermostat and the other for the thermometer. In the middle of one end of the cover is another 1½-inch opening for the cold-water tube. The openings are lined with galvanized iron collars, fitted around the inside edges and soldered water-tight.

All metal on the tank and cover is given three coats of water-proof paint. The cost of a completed tank and cover is approximately thirty dollars.

Cans

The soil cans (Fig. 3A) are suspended in the openings of the covers described above. They are made of 24-gauge galvanized iron with seams well soldered so as to be water-tight. They are 9½ inches deep, 8 inches in diameter at the top, and slightly less than 8 inches at the bottom so that

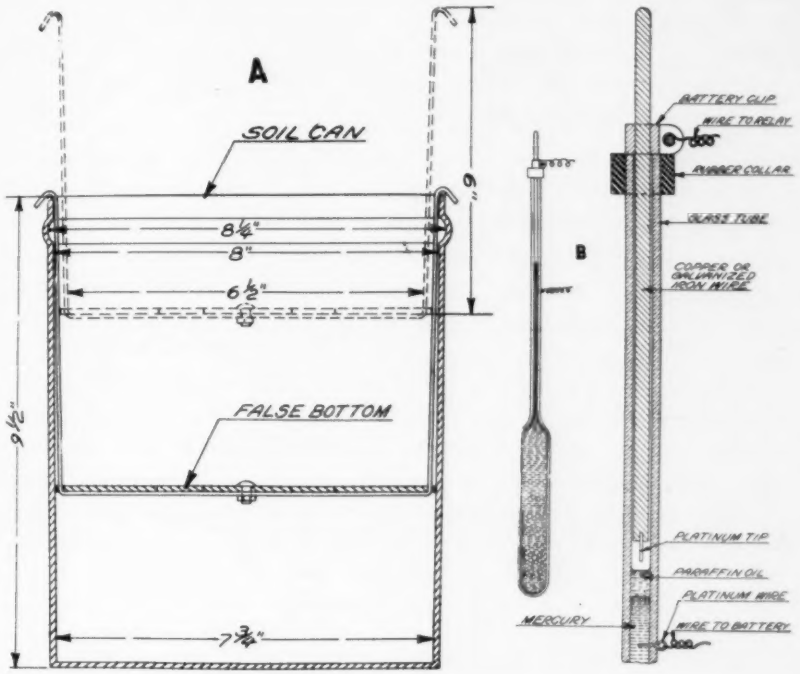

FIG. 3. A. Diagram showing the dimensions and structure of the soil cans together with the device used for transferring seedlings to a greenhouse bench. B. Thermostat used for regulating temperatures in the soil temperature-control tanks.

they can be removed easily for daily weighing and watering. The cans are beaded one inch from the top to support them in the openings. They can be made for about seventy-five cents each.

Heater Tube

A vertical heater tube, illustrated in figure 1, has been adopted in the temperature-control tanks at Arlington Experiment Farm instead of the troublesome "gooseneck" type of heater tube, commonly used in the Wisconsin tanks. This vertical heater tube is 3 inches in diameter and extends from the bottom of the tank to 2 inches above the cover. A metal collar soldered about the tube just below the tank cover prevents it from slipping

up through the opening and also serves as a support for the center of the cover. The bottom of the tube is held in place by a metal collar soldered to the bottom of the tank. A 250-watt luminous radiator bulb, or other heater, is placed in the bottom of the tube and immersed in kerosene, which serves to conduct the heat away from the heater. The wires from the heater pass through a close-fitting transite disc and then through several inches of well packed mineral wool. This prevents the kerosene from vaporizing and keeps the heat from rising to the top of the tube. A metal cover fits closely over the heater tube and the wires pass through a short porcelain tube fitted into a hole in the center.

Heaters

Of the various types of heaters tried up to the present time, the Westinghouse 250-watt luminous radiator bulbs have been found most satisfactory. Other types, especially the General Electric cartridge unit, under certain conditions, have given good service. Although rather fragile, the luminous radiator bulb is convenient to use in connection with the heater tube described and in trials conducted by the writer with an ordinary watt-hour meter it was found to be relatively economical in current consumption in maintaining the higher temperatures. The cost of the Westinghouse radiator bulbs is $2.50 each. An ordinary carbon light bulb is suitable for maintaining medium temperatures providing the air temperature does not vary too much.

Relays

A relay connected in series with a battery and with a simple mercury thermostat immersed in the water of the temperature-control tank is used to control the heating current (Fig. 1). At the lower temperatures relays are used also to control the motors operating the cold-water pumps (Fig. 4).

If a direct electric current is not available and a battery must be used to operate the relays, it is desirable to secure a relay which operates on a very small amperage. A 250-ohm telegraphic relay is satisfactory. When operated by a 6-volt battery, 18 such relays draw less than ½ ampere. These relays cost about seven dollars each.

Where direct electric current is available a battery is not needed and a cheaper relay will suffice. The direct current can be reduced to the desired amperage by inserting resistance in the line and a 50-ohm pony relay, costing about three dollars, will then answer the purpose.

The relays should be examined and adjusted, occasionally as the hinge screws often work loose and throw the contact points out of alignment. The contact points should be kept clean, and if they fuse due to too heavy

a current passing through them they should be replaced by tungsten or molybdenum points.

Battery

As stated above, a direct electric light current reduced to the proper amperage by inserting resistance in the line is more satisfeatory for operating relays than is a battery current, as the former is more constant and dependable. However, if only alternating current is available a battery must be used unless special relays are employed.

An ordinary sulfuric acid, lead-plate storage battery of 6 volts and of 110 ampere-hours capacity has been found satisfactory. This operates eighteen 250-ohm relays for more than a month before recharging is necessary. It is well to have another battery available for use while recharging the storage battery. A rectifier may be employed for recharging if no other means is available.

Thermostat

The thermostat employed (Fig. 3-B) was originally devised in the Department of Plant Pathology of the University of Wisconsin. It consists of a mercury bulb about 4½ inches long and ¾ inches in diameter. It has a neck about 6½ inches long with a bore of about ⅛ inch or less. Three inches above the junction of the bulb and the neck a piece of No. 26 platinum wire, about ½ inch long, is sealed into the glass tube with one end projecting into the bore to contact with the mercury and the other outside to attach to a wire leading to the relay. A close-fitting platinum-tipped wire plunger is inserted in the upper end of the neck and there held in any given position by a battery clip to which is attached a wire leading to the battery. The circuit is completed by a wire from the battery to the relay.

To adjust the thermostat for any given temperature it is immersed in water at that temperature until the mercury has acquired the temperature of the water. The platinum-tipped wire plunger is then adjusted so that it barely touches the mercury column.

The top of the mercury column may be covered with a thin layer of high grade paraffin oil to prevent it from oxidizing.

When the heater has brought the water in the tank to the desired temperature the mercury column in the neck of the thermostat makes contact with the platinum-tipped wire. This closes the circuit through the thermostat, the battery, and the relay coils and breaks the heating current by separating the contact points of the relay. When the temperature of the water has dropped sufficiently to separate the thermostat contacts, the battery circuit is broken and the contact points of the relay come together,

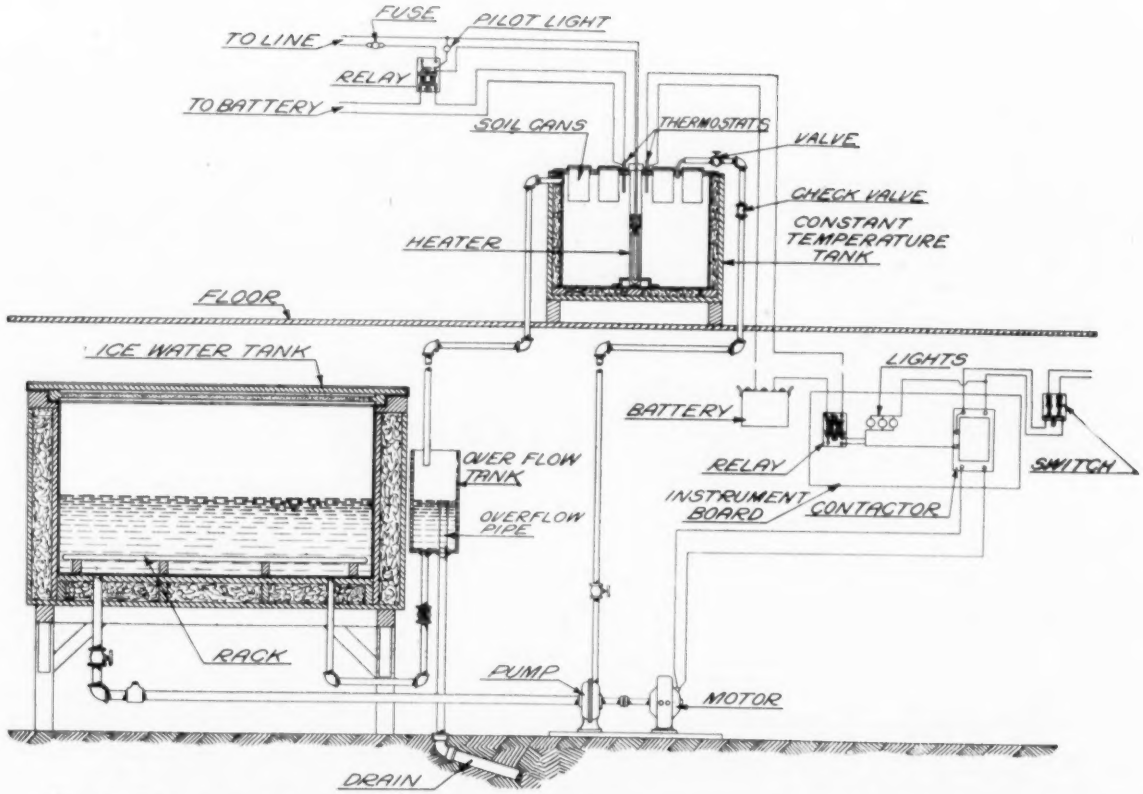

FIG. 4. Diagrammatic view of the soil-temperature-control equipment at Arlington Experiment Farm. The ice-water tank, pump, motor, etc., are in the basement below the temperature-control tanks, but if need be they may be on the ground floor, if so arranged that the top of the overflow tank is below the level of the water in the soil-temperature-control tanks. Only one pump, motor and contactor are represented here although several are used. At the higher and lower temperatures only one thermostat in each tank is necessary, but at temperatures between 12° C. and 20° C. two thermostats are advisable, one for heater control and the other for regu-

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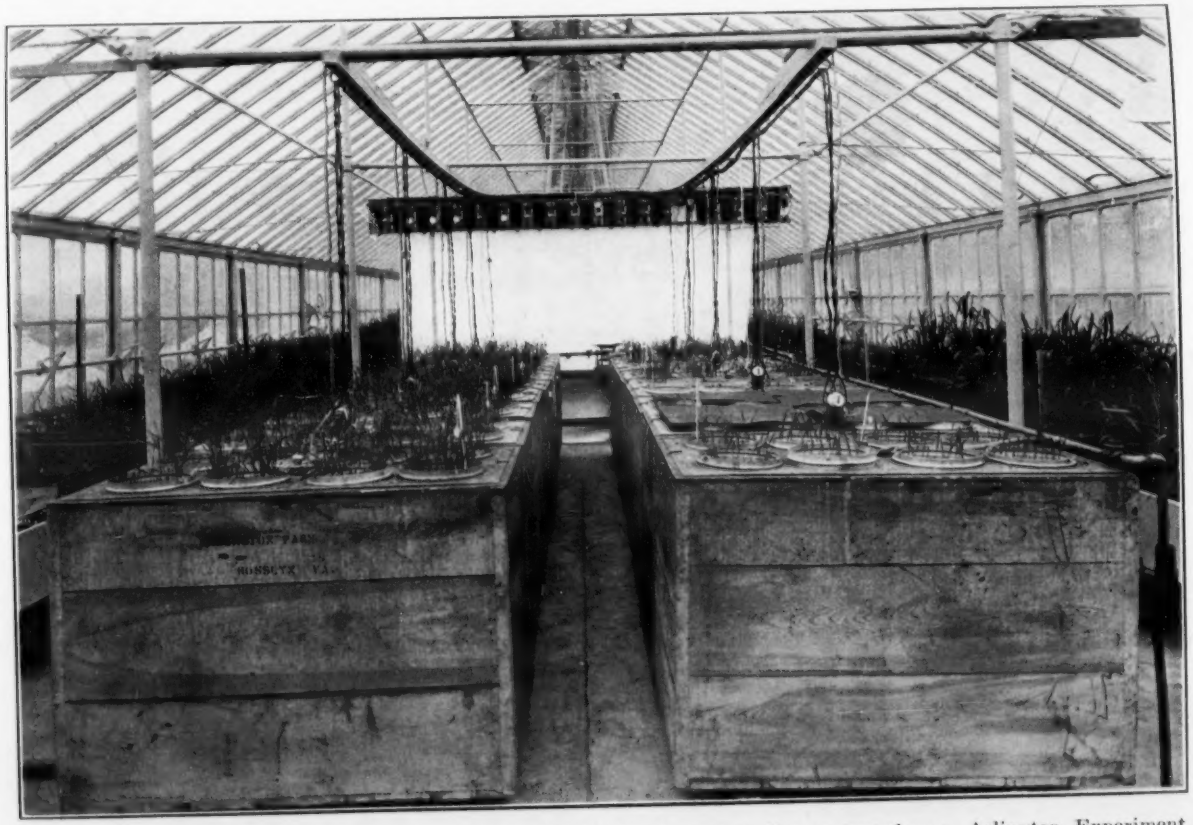

FIG. 5. General view of the soil-temperature-control tanks in the cereal disease greenhouse, Arlington Experiment Farm. On the switchboard is a relay, fuse and pilot light for each heater. Each relay is numbered to correspond to the number on the tank, the heater of which it operates.

closing the circuit through the heater and also through the pilot light on the switchboard. Although this thermostat is not entirely satisfactory, it is inexpensive, easily made, readily adjusted and sufficiently sensitive to keep the water within a half degree of the desired temperature.

Switchboards

The relays used to control the heaters are mounted on a switchboard (Fig. 1). For every heater in a temperature-control tank there is a corresponding relay, fuse and pilot-light on the switchboard. Each pilot-light indicates whether or not the corresponding heater is in operation. The wiring for this installation is shown in Fig. 1 and 5.

Another switchboard contains a fuse, relay, bank of lights and magnetic contactor for each cold-water pump. This installation is described above and illustrated in Fig. 4.

Low Temperature Equipment

Constant low temperatures in a number of the tanks are maintained by the thermostatically controlled flow of ice-cooled water into them whenever their temperatures rise above the desired points. This is accomplished by the apparatus shown in Fig. 4. The inside dimensions of the ice-water tank are 3 feet by 6 feet by 4½ feet deep. The details of its construction are shown in Fig. 5. Ice is placed on the rack in the ice-water tank. Water enters from the overflow tank and after being cooled is drawn out by a pump driven by a thermostatically controlled motor. The cold water is pumped to the temperature-control tanks,[3] and enters each tank through a tube attached to a valved connection in the cold water line. These valves are adjusted so that the water flows at a rate necessary to obtain temperatures slightly below those desired. The rates of flow for different tanks held at the same temperature are about equal. The water is returned to the overflow tank from which it flows back into the large tank to be re-cooled and re-circulated.

The height of the water in the overflow tank and in the ice-water tank is governed by the height of the adjustable overflow pipe. In warm weather or when more tanks are to be cooled the water level is raised. In cold weather or whenever fewer tanks are in operation the water level is lowered, thus using less ice.

A wire screen over the outlet in the ice-water tank and a strainer in the pipe line prevent dirt from getting into the pumps. A valve below the

[3] In this case the ice-water tank pumps, etc., are in a basement below the greenhouse. However, this part of the equipment can be located on the ground floor providing the level of the water in the temperature-control tanks is higher than the top of the overflow tank so that the water will return to the latter by gravity.

ice-water tank and another above each pump make it possible to shut off the water when necessary. Check valves prevent the water in the temperature-control tanks from siphoning back when the pumps stop.

An air temperature as near 15° C. as possible is maintained in the greenhouse where the temperature-control tanks are located. However, on cold winter nights the greenhouse temperature occasionally goes as low as 10° C. Therefore thermostatically controlled heaters are necessary in the tanks which are kept at 15° C. In warmer weather the greenhouse temperature often rises above 20° C. so that it is necessary to use cold water to prevent the temperature of the 20° tanks from going too high. This may be done by means of a thermostatically-controlled pump as in the case of the lower temperature tanks. A thermostat suspended in the water of one tank controls the flow of cold water into all of the tanks at that same temperature. When the temperature of the water rises above the desired point, the mercury column in the neck of the thermostat rises and makes contact with the platinum-pointed wire plunger. This closes the circuit through the battery and the relay coils. The relay-contact points are so arranged that the power circuit is closed whenever the battery circuit is closed. Therefore, the motor operates the pump until enough cold water has been added to the tanks to lower the water temperature to the desired point.

The ½ and ¾ horse-power motors used to operate the pumps draw more current than can be passed through the contact points of the relays without causing them to fuse. Therefore, a magnetic contactor is used in connection with each relay. The installation of this is shown in Fig. 4. The leads from the main line are attached to the two upper posts of the contactor. Two wires from the lower posts lead to the motor. A bank of two or three 50-watt carbon filament bulbs in series with the relay and the armature of the contactor is connected in parallel with the contactor itself. When the battery current actuates the relay coils, the electric light circuit is closed through the bank of lights, the relay points, and the contactor armature, thus causing the contactor to close the circuit to the motor.

This apparatus kept the water in six of the temperature-control tanks at 8° C. for six months without much trouble, and at 4° C. for a shorter period. Another pump similarly controlled was used for the 15° tanks. In warm weather enough water was allowed to trickle into the 20° tank from the water line leading to the 10° tanks to keep their temperature from rising above 20° while the heaters kept them from being cooled bleow 20°. About six tons of ice were used each month.

EXPERIMENTAL METHODS

Type of Soil Used

One of the difficulties experienced in carrying on soil-temperature studies is encountered in the tendency of the soil to bake at the higher temperatures. This was overcome by using a soil containing a high percentage of organic material. A supply of well-decayed leaf mold was secured and sifted through a 4-mesh sieve. This material was mixed with an equal quantity of light clay loam, also sifted through a 4-mesh sieve. The water-holding capacity of this mixture was 72%, and at no time did it show any tendency to bake.

Soil Moisture

Soil temperature being the variable factor, it is necessary, of course, to keep the soil moisture uniform at the different temperatures. After screening and thoroughly mixing enough soil to fill all the cans used in a series, the moisture-holding capacity and the moisture content of the soil are determined. The soil is then spread out and sufficient water added with a sprinkler to obtain the desired moisture content. It is allowed to lie covered long enough for the water to permeate the soil so that the latter can be thoroughly mixed without puddling. When properly mixed, a uniform, weighed amount of soil is placed in each can. When the cans are suspended in the tanks, the surface of the soil should be slightly below the water line. Evaporation from the soil is reduced by placing a ½-inch layer of ground cork on the surface after the seeds have been sown. The cans at the higher temperatures are weighed daily and those at the lower temperatures less frequently. Any water lost through evaporation or by transpiration is replaced. At the higher temperatures, the water is applied around the edges of the cans, as that is where most of the drying occurs. The water used is of the same temperature as the soil. It may be taken from the tanks, or, if steam is available, tap water may be heated to the proper temperature. The watering device used is a cylindrical bucket six inches in diameter and about 12 inches deep. Near the bottom is an opening with an attachment for a quarter-inch rubber tube. This bucket is suspended overhead, and by means of the rubber tube a stream of water can be directed against the inside of the can, thus applying the water around the edge where it is needed most. The tube is provided with a pinchcock with which to shut off the water.

The scale used for weighing the cans is of the platform type commonly used in greenhouse experiments. It is sensitive to one gram and has a maximum capacity of 20 kilograms.

TEMPERATURE ADJUSTMENT AND MAINTENANCE

The water in the tanks is brought to the desired temperatures by the use of steam a day or two before any seeding is done so that the soil will have acquired the proper temperature by that time. A standardized thermometer is suspended in the water in each tank so that the bulb is three inches below the surface. Another thermometer is placed in the soil in one of the cans in each tank so that the bulb is at the seed level and one and a half inches from the side of the can. Temperature readings are taken three times daily. A typical day's reading (Table 1) shows the relation between the greenhouse air temperature, the water temperature, and the soil temperature. The temperature of the soil depends not only on that of the water but also to some extent on the air temperature and the intensity of the solar radiation.

The layer of ground cork on the surface of the soil helps to regulate the soil temperature by reducing radiation at the higher temperatures, and by shutting out the heat of the sun, to some extent. When the sun's heat becomes intense, partial shading with cheesecloth or thin muslin is advisable. Care should be taken, however, not to make the shading too heavy or too prolonged as the metabolism of the plants is affected by pronounced reduction in light intensity.[4] Even with a constant water temperature it is difficult to maintain constant soil temperatures if the range in air temperature is excessive.

Seeding

Uniformity in depth and in other details of seeding is important. Cereal seeds are sown usually at a depth of one and a half inches. This depth is secured by removing a measured amount of soil from the can. The seeds are placed in a circle equidistant from the center and 1½ inches from the side of the can. This is advisable because the temperature varies slightly at different distances from the side of the can. A cardboard disc five inches in diameter is helpful in placing the seeds the proper distance from the center and from each other. After tamping the seeds gently to hold them in place, the 1½ inches of soil are replaced, a layer of ground cork added, and the can properly labeled and covered with heavy paper until emergence begins. The paper is then removed.

Transplanting

As infection by many of the cereal diseases such as bunt, for example, occurs only during the seedling stage of the plant, it is not always neces-

[4] Garner, W. W., and Allard, H. A. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. Jour. Agr. Research, **18**: 553–606, 1920.

TABLE 1.—*Temperatures of greenhouse air, desired soil temperatures, and actual temperatures of the water (W) and the soil (S) in 12 temperature-control tanks, Nos. 1–12, at 8 A. M., 12 M., and 4 P. M., on a typical day, November 15, 1923.*

Soil temperatures desired		32° C				28° C				24° C				20° C				15° C				10° C			
Tank numbers		1		2		3		4		5		6		7		8		9		10		11		12	
Hour	Air temp	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S	W	S
	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
8 A. M.	14	33.5	31.5	33	31.0	30.0	27.0	30	27.5	25.0	23.5	25.0	23	20	19.5	20.0	20	15	14.5	15	14.0	7.5	9	8.0	9.0
12 M.	16	34.0	32.0	34	32.0	30.5	28.5	30	28.0	25.5	24.5	25.5	25	20	20.0	20.5	21	15	15.5	15	15.5	8.0	10	8.5	10.5
4 P. M.	15	34.0	32.0	34	31.5	30.0	28.0	30	28.0	25.0	24.0	25.0	24	20	20.0	20.0	20	15	15.0	15	15.0	8.0	10	8.0	10.0

sary to grow the plants at the different temperatures beyond the stage of fifth, fourth, or even the first leaf. They may then be transferred to the greenhouse bench or even transplanted to the field if weather conditions permit, and the cans and tanks made available for another series. The simple device used by the writer for transferring plants from the cans to the greenhouse benches is shown in Fig. 3. It consists of a perforated galvanized iron disc 6½ inches in diameter suspended in the cans by means of two heavy galvanized iron wires hooked at the upper ends over the edge of the can. When the plants are ready for transplanting, the soil is first generously watered. It is then easily lifted out of the cans by means of the heavy upright wires and may be transferred to the bench where other soil is packed about it. Here the plants are grown to maturity or to a stage at which final notes on them may be taken.

OFFICE OF CEREAL INVESTIGATIONS,
BUREAU OF PLANT INDUSTRY,
UNITED STATES DEPARTMENT OF AGRICULTURE.

PERMANENT SPIRALS FOR TAGS

DEAN A. PACK

In connection with the work at this station, on the breeding of sugar beets, the author has devised an attachment for fastening identification tags to beets. This attachment consists of a galvanized spiral permanently fastened, by one end, to a metal tag carrying the identification number. Tags and spirals are illustrated in figure 1.

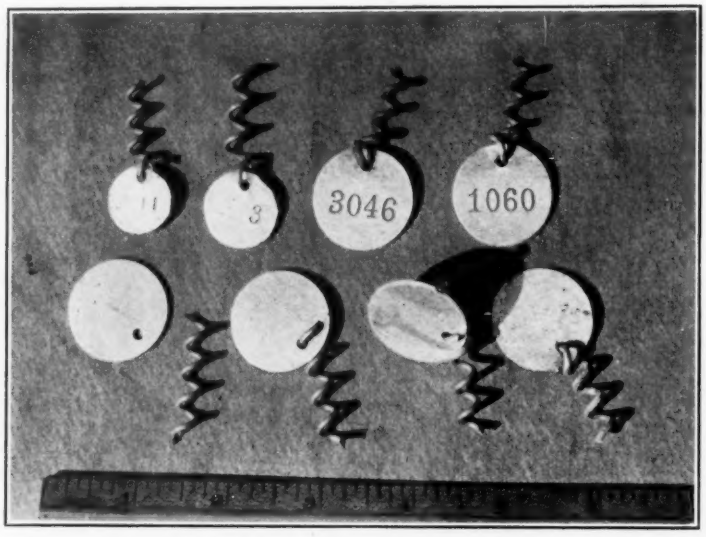

FIG. 1. Various sized tags and the attachment of the spiral to a tag.

These spiral tags may be used for various types of breeding, physiological, pathological, and field work, where plants or parts of plants are to be identified. The spiral tag is very desirable for some types of experimental work, because it has a constant weight due to being constructed entirely of metals. The tags are fastened to the plant by turning the spiral to the right into its tissues, and are removed by turning the spiral to the left. Some uses of these tags are indicated in figure 2.

The tags may be of various sizes and stamped from, either aluminum or brass. The spirals are made by winding number fifteen galvanized wire about a second wire 3/16 of an inch in diameter. Ten feet of number fifteen wire will make from 145 to 150 turns, and produce a coil about ten inches long. This coil is then stretched to form a spiral about four and one half feet long. It is then cut into the proper tag spirals, having four turns each.

FIG. 2. Tags attached and in use.

FIG. 3. The construction of spirals.

One turn is used for fastening the spiral to the tag, and the other three turns fastens securely the spiral in the beet. The size of the wire used in making these spirals, and the diameter of them, will depend upon the type of tissue one may be working with. The various steps in the construction

of these spirals and their attachments to the tags, are represnted in figs. 1 and 3.

To a large extent, the value of a tagging method depends upon the degree of certainty one can place upon the method. There is no hesitation in the use of these permanent spiral tags. The spirals and tags are made of metals that do not readily corrode. The numbers being stamped into the metal tags are easily read and never become rubbed off. Each tag is permanently attached to its spiral, and should never be taken off. There is little danger of a tag becoming detached from a plant, because of the structure of the spiral. It requires a straight pull of from 48 to 79 pounds to draw one of these spirals out of an ordinary beet. This force is about ten times that required to draw the nails of a wooden label or tag out of a beet.

These spiral tags have been used during the past three years at this station with a great savings of time, money and labor.

PHYTOPATHOLOGICAL NOTES

Third Pan-American Scientific Congress. The Second Pan-American Scientific Congress was held in Washington from December 27, 1915, to January 8, 1916, and at that time the city of Lima in Peru was designated as the seat of the Third Congress. The sessions will commence November 16 and will last over the fortnight following. All branches of science will be represented in nine sections. Plant pathology falls under the Section of Biology, Agriculture and Related Sciences of which Dr. Wenceslao F. Molina is president. Mr. M. V. Villaran is president of the Congress and Mr. Jose J. Bravo, Secretary General, address, Apartado 889, Lima, Peru. The Organization Committee is inviting some of the more notable of American scientists to contribute papers and if possible to attend the Congress. If any of the members of the American Phytopathological Society have papers that they would like to contribute, or if they find that they can attend the Congress, it is suggested that they communicate with the secretary of their Society.

Horticulturists, entomologists and pathologists to meet in British Columbia. The Northwest Association of Horticulturists, Entomologists and Plant Pathologists will hold their seventh annual meeting at Penticton, British Columbia, August 26 to 29, 1924. The membership of this association includes those interested in the three sciences in the states of Oregon, Washington, Idaho, Utah, and Montana and in the province of British Columbia. The Pacific Division of the American Phytopathological Society will also hold their annual meeting at the same time and place. This will be one of the most important scientific meetings ever held in the Pacific Northwest. Further information regarding these meetings can be secured by addressing either Prof. W. T. Hunter, Secretary of the Northwestern Association of Horticulturists, Entomologists, and Plant Pathologists, care of the Experimental Farms, Summerland, B. C., or Prof. Chas. W. Hungerford, Secretary of the Pacific Division of the American Phytopathological Society, University of Idaho, Moscow, Idaho.—C. W. HUNGERFORD.

Publication of foreign papers. In accordance with instructions given the Committee on International Phytopathology appointed by the Society at the Cincinnati Meetings, arrangements have been made with Dr. H. M. Quanjer, of the Phytopathological Institute of Wageningen, Holland, to act as editor of Phytopathology for Europe and to solicit subscriptions and to receive and transmit papers offered for publication in the Journal in

either English, French, or German, the total of such papers not to exceed 100 pages during the year. A special subscription rate has been offered in those countries whose currency is below par. Full information regarding this plan can be obtained from Dr. Quanjer. It is hoped that our European colleagues will accept this opportunity to advance our knowledge and bring about closer and better phytopathological relations.—C. L. SHEAR, *Chairman.*

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